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# The Araguaia Belt, Brazil: Part Of A Neoproterozoic Continental-Scale Strike-Slip Fault System

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**Abstract:** The Araguaia Belt is part of the Tocantins Orogen, a Neoproterozoic orogen that formed during the collision between the Amazonia, São Francisco/Congo and West African Paleo-Continents. This collision contributed to the assembly of West Gondwana. We mapped parts of the Araguaia Belt in its south and central portions in northern Brazil. Our mapping suggests two phases of deformation. The first resulted in the development of N-S trending amphibolite-facies transpresssional structures with a reverse-sinistral movement with vergence towards the Amazonian Craton on the west. The age of this deformation phase is possibly Paleoproterozoic. The second phase generated N-S dextral strike-slip faults that cross-cut older structures. This phase was accompanied by retrograde metamorphism. We propose that these strike-slip faults connect with the east-west trending dextral strike-slip faults in the Borborema Orogen on the northern margin of the São Francisco Craton. Movement on faults fringing the Amazonian Craton combined with that of the Araguaia-Borborema strike-slip system, accommodated lateral escape of terranes wedged between the Amazonian and São Francisco-Congo Cratons during the Neoproterozoic.

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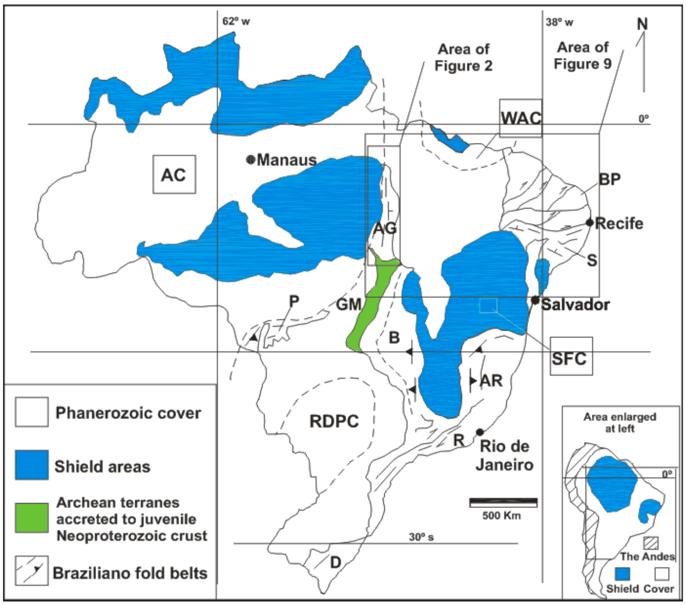
## Introduction

The assembly of Western Gondwana in the late Precambrian involved various continental fragments derived from the break-up of Rodinia Supercontinent during the Brasiliano-Pan-African Orogeny (750-550 Ma., Hoffman, 1991; Dalziel, 1992). Four continental blocks (Amazonia, São Francisco/Congo, West Africa and Kalahari) interacted diachronously in complex kinematic patterns involving collisions, wrench tectonics, and extensive pre-to post-tectonic magmatism (e.g. Alkmim et al., 2001). These collisions resulted in the amalgamation of cratonic nuclei to form the western part of the Gondwana continent.

The Araguaia Fold Belt in central Brazil ( Figure 1 ) occurs along the eastern border of Amazonian Craton and the western border of the São Francisco Craton. It is more than 1000 km long and records interactions between the Amazonia, São-Francisco/ Congo and West African Continents. The Araguaia Belt is a complex and poorly known fold belt. Its outer zone contains bodies of ultramafic rocks that may represent oceanic crustal fragments. The ultramafic rocks have been thrust over sedimentary rocks of unknown age. Also, there is an abrupt change of structural and metamorphic styles between rocks of the outer zone of the belt, where sedimentary and anchimetamorphic rocks prevail, and the inner zone, where metamorphism reaches amphibolite facies.

**Figure 1. Tectonic map of Brazil**




Tectonic map of Brazil, with the distribution of cratons and fold belts. RDPC, Rio de la Plata Craton; WAC, West African Craton; AC: Amazonian Craton; SFC: São Francisco Craton; GM: Goiás Massif. Fold belts: AG: Araguaia; P: Paraguai; B: Brasília; AR: Araçuaí; R: Ribeira; D: Dom Feliciano; S: Sergipano; BP: Borborema Province.

The structure of the Araguaia Belt formed during a contractional event with two phases of deformation. The first is represented by north-south trending, left-lateral thrusts associated with west vergent folds. These oblique-slip thrust faults have a left-lateral strike-slip component and it has been suggested that they formed by reactivation of normal faults that penetrate basement (Hasui and Costa, 1990; Hasui et al., 1994, and Abreu et al., 1994). The second phase has the same orientation and vergence of the first phase and involves deformation (faulting and folding) of previously formed structures (Abreu et al., 1994). Most authors interpret this event as a result of an advanced stage of continental collision (e.g. Hasui et al., 1994). NNW/SSE-trending brittle wrench shear zones are also reported and are responsible for rotation of previously nucleated structures (Santos and Costa, 1995).

In this paper, we review the structure of the Araguaia Belt and present new structural data and discuss their significance in the context of the interaction of Amazonia, São Francisco-Congo and West Africa continents during the Brasiliano-Pan-African orogeny. This paper is therefore concerned with the larger issue of the tectonic role the Araguaia Belt during the collisional scenario of West Gondwana amalgamation.

## The Araguaia Belt within the Gondwana Reconstruction

Two interrelated Neoproterozoic orogenic systems can be recognized between the Amazonian, West African and São Francisco/Congo cratons. The first is the Borborema Orogen and the Sergipano Fold Belt, on the northern margin of the São Francisco Craton. The second is the Tocantins Orogen, located between the Amazonian and São Francisco cratons that includes the Brasilia and Araguaia Fold Belts and the intervening Goiás Massif. ( Figure 1 ).

The Brasília Fold Belt extends for over 1000 km along the western margin of the São Francisco Craton. It involves Archean basement as well as Meso- and Neoproterozoic clastic strata (Valeriano et al., 2004). Tectonic and metamorphic vergence is towards the cratonic area. Folds and thrusts in the orogen are overprinted by transcurrent faults (Fonseca et al., 1995, Seer, 1999; Valeriano, 1999). The Goiás Massif represents a complex crustal fragment, consisting of typical Archean TTG-greenstone terrains, large layered Mesoproterozoic mafic and ultramafic intrusions (Ferreira Filho et al., 1994), and Mesoproterozoic A-type granites (Pimentel et al. 1991, Pimentel et al., 1999).

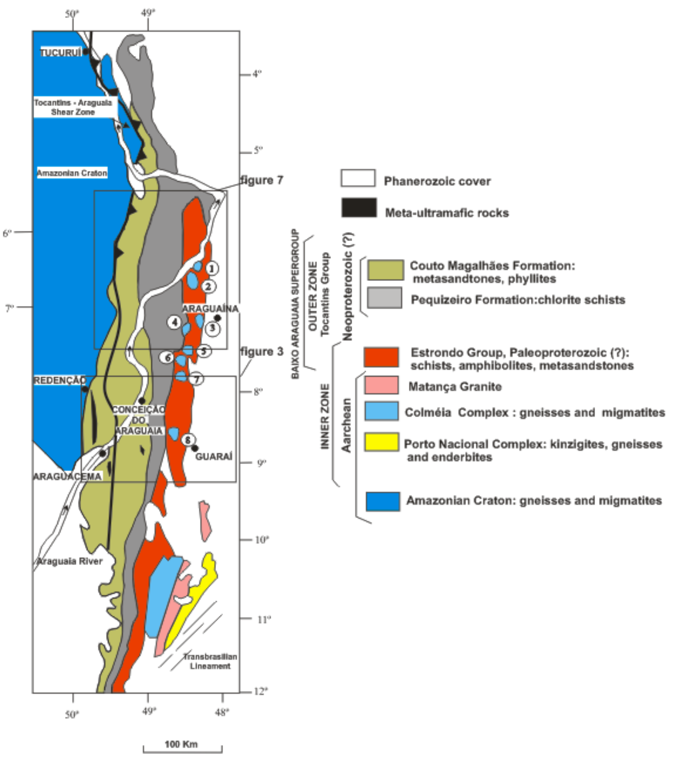
The Borborema Province is part of a Brasiliano-Pan-African orogen that continued into Africa prior to Gondwana breakup. It consists of an array of E-W trending right-lateral strike-slip shear zones and a conjugate sinistral NE-SW trending set in northeastern Brazil (Caby et al., 1991). The shear zones cut across gneiss and migmatite complexes of the basement as well as supracrustal units represented by metamorphosed sedimentary and volcanic rocks. These give rise to linear, narrow fold belts. Syn-kinematic granitic magmatism intruded the orogen (Brito Neves, 1975; Neves and Vauchez, 1995, Weinberg et al., 2004). According to Vauchez et al. (1995) mylonitization developed between 600-570 Ma under high temperature conditions and was coeval with partial melting at shallow crustal levels.

The Sergipano Fold Belt is a frontal fold-thrust belt that defines the northern boundary of the São Francisco Craton in Brazil and continues into Africa, as the Oubanguide Fold Belt. This south-verging belt trends east-west and displays a triangle-shape metasedimentary wedge in map view (Davison and Santos, 1989; Silva, 1995).

## Geology of the Araguaia Belt

Barbosa et al. (1966) and Almeida (1967) were the first to describe the Araguaia Belt which they called Paraguay-Araguaia Belt. These authors considered the belt to be an orogen extending for over 2500 km long bordering the Amazonian Craton. Now, the Araguaia Belt is considered to be separated from the Paraguay Belt by the Goiás Massif. The Araguaia Belt extends for over 1000 km from Marajó Island at the equator to 11o S latitude, and it borders the east side of the Amazon Craton ( Figure 2 ). It is less than 150 km wide because it is covered eastward by sedimentary rocks of the Paleozoic Parnaíba Basin. The Paraguay Belt is a northwest-verging arcuate fold-thrust belt that lies along the southern margin of the Amazon Craton ( Figure 1 ).

**Figure 2. Geology of the Araguaia Belt**




Geology of the Araguaia Belt (after Hasui & Costa, 1990. Moura & Gaudette, 1993). Dome structures: (1) Xambioá; (2) Lontra; (3) Grota Rica; (4) Cocalândia; (5) Cantão; (6) Rio Jardim; (7) Cunhas; (8) Colméia.

The Araguaia Belt may be divided into two main zones ( Figure 2 ). The inner zone involves basement outcrops along a 250 km-long line of eight doubly-plunging anticlines (or domes). The basement occurs in the center of the domes and is surrounded by metamorphosed supracrustal rocks (metasedimentary rocks of the Estrondo Group). The largest dome is the Colméia Dome, an elongated body of 35 x 20 km. The next larger domes are the Xambioá dome (11 x 9 km) and the Lontra dome (20 x 9 km), which trend WNW, and are separated by a synformal keel of supracrustal rocks. Previous studies concerning the evolution of these domes suggest that they are either a result of crustal diapirism (Hasui et al., 1984; Santos et al., 1984) or that they simply are doubly plunging anticlines that resulted from SE-NW contraction (Costa, 1980; Hasui and Costa, 1990; Abreu et al., 1994; Santos and Costa, 1995).

Supracrustal units of the inner zone involve rocks of the Baixo Araguaia Supergroup divided into two units: the basal Estrondo Group and the upper Tocantins Group.

Rocks of the Estrondo Group are sedimentary rocks metamorphosed up to amphibolite facies. According to Abreu and Hasui (1978) and Gorayeb (1989), the Estrondo Group can be divided into two formations. The basal one is the Morro do Campo Formation, consisting of orthoquartzites and micaceous quartzites with interbedded layers of biotite- schists and graphite-muscovite schists. Upwards, the Xambioá Formation includes muscovite-biotite schists with interbedded layers of amphibolite, quartzite and dolomite.

The outer zone borders the Amazonian Craton to the west. It is composed of psammites and pelites of the Tocantins Group that can be divided into two units. The basal unit is the Pequizeiro Formation that consists of quartz-chlorite schists and phyllites. The top formation is the Couto de Magalhães Formation that includes slates and phyllites with minor quartzites, metacherts and metacarbonate rocks. Within the western part of the zone, rocks are unmetamorphosed, and thus contrast markedly the amphibolite-grade rocks in the inner zone to the east. A prominent lineament occurs along the contact between the Araguaia Belt and the Amazonian craton. This feature, the Tocantins-Araguaia lineament ( Figure 2 ), was first described by Kegel (1965). This lineament comprises a set of shear zones that separates the Amazonian Craton to the west, where structures visible on aerial photograph trend NW to EW and the Araguaia Belt to the east, where structures trend N-S. Almeida (1986) proposed that the lineament represents a zone containing various deep shear zones, extending over 850 km along the eastern border of the craton from latitude 10o 30' to 3o 30'S. According to Almeida (1986), most faults are concealed under the Baixo Araguaia sedimentary rocks and recent cover. However, local observations suggest that the southern segment is vertical whereas to the north, close to the Tucuruí Dam (4o S, 50o W,  Figure 2 ) it dips eastward, becoming a thrust fault verging WNW and truncates metasedimentary rocks of the Tocantins Group (Trouw et al., 1976). The precise kinematics and age of the fault zone have not been determined. The fault also truncates mafic-ultramafic bodies ( Figure 2 ) now schists and serpentinites. According to Gorayeb (1989), most ultramafic bodies display massive internal textures whereas the borders are generally brecciated or present mylonitic foliation parallel to the trend of Tocantins Group sedimentary rocks. Several authors consider the mafic and ultramafic bodies to represent fragments of ophiolite sequences (Gorayeb, 1989; Souza et al., 1995; Teixeira, 1996; Kotschoubey et al., 1996) related to the Brasiliano orogeny.

### *Geochronological Constraints on the Tectonic Evolution*

Although an understanding of the Araguaia Belt is essential for developing models for the assembly of Gondwana, there are few reliable radiometric dates on rocks of the belt. Most published ages were obtained by K/Ar and Rb/Sr dating techniques. There are a few Sm/Nd and some Pb/Pb ages available but no Ar/Ar and U/Pb ages. Sm/Nd model ages (Tdm, whole rock) for the basement rocks range between 3.4 and 2.9 Ga. (Cordani & Sato, 1999; Moura & Gaudette, 1993). Moura & Gaudette (1993) also obtained a date of 2.85 Ga using Pb/Pb method. These data suggest that the main period of basement protolith formation was in the Archean. K/Ar and Rb/Sr dates (Hasui et al., 1980) indicate reworking during the Paleoproterozoic (1.8 Ma) and Neoproterozoic (0.5 Ma).

A 2085 Ma Pb/Pb age for gneisses in the southern portion of the Araguaia Belt (Souza and Moura, 1995; Moura and Souza, 1996) suggests that an episode of crustal accretion occurred during Paleoproterozoic. Paleoproterozoic crustal accretion or reworking (?) is also supported by a series of Rb/Sr and K/Ar ages (Hasui et al., 1980, Lafon et al., 1980). A Pb/Pb age of ca 1851±41 Ma was obtained for the Serrote granite at the southern segment of the Araguaia Belt (Sousa and Moura, 1995). Paleoproterozoic ages were also obtained for the basalts of the mafic/ultramafic units. Pb/Pb ages of 2083±4, 2062±3, 2052±5 and 2035±3 Ma for magmatic zircons indicate important magmatic activity (Gorayeb et al., 2001).

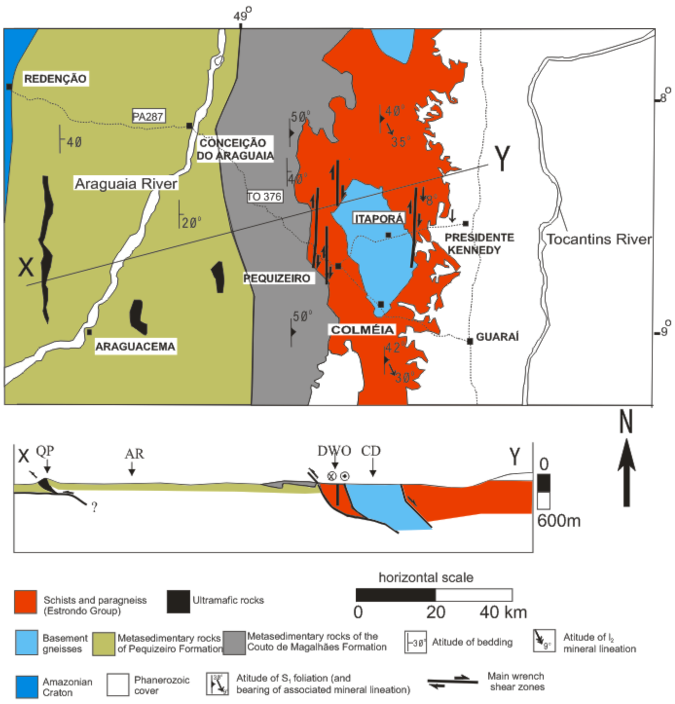
The age of deposition of the supracrustal units is still unknown. Because of the significant contrast in metamorphic and structural style between the Estrondo and Tocantins Groups, it appears that the units are not the same age, with the high grade Estrondo being older. Lafon et al (1980) obtained a Rb/Sr age of 497 Ma for the Ramal do Lontra granite which cuts the Estrondo rocks. Moura and Gaudette (1993) obtained Pb/Pb ages in single zircons of 583 72, 498 19 and 583 39 Ma in granite veins that also cut the Estrondo Group. K/Ar data only constrain cooling ages to be between 560 - 420 Ma (Hasui et al., 1975; Herz et al., 1989).

## *Tectonic Overprint in the Araguaia Belt*

### *Guaraí-Redenção Section*

The geological section between the tows of Guaraí (Tocantins State) and Redenção (Pará State, Figure 3 ) is considered to be the type section of the Araguaia Belt. The section extends for 200 km along the state roads TO 376/ PA 287. From west to east, the following lithologic assemblages are distinguished: the Colméia Complex, the Estrondo and Tocantins Groups.

**Figure 3. Geology of the Guaraí-Redenção Section**




See Fig. 2 for location. Geology after Silva et al. (1974). QP: Quatipuru ultramafic body; AR: Araguaia River; DWO: Dextral wrench overprint on west-verging contractional fabric; CD: Colméia Dome.

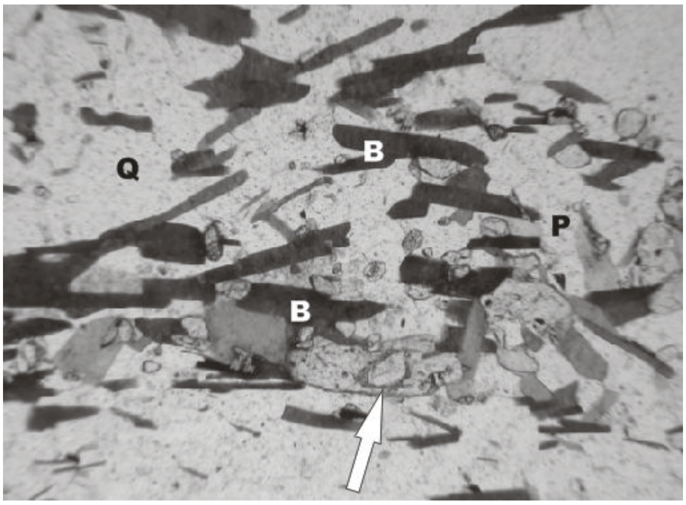
### *Colméia Complex*

The Colméia Complex crops out in the core of Colméia Dome. The longest dome axis extends north-south for 35 km whereas the shortest axis extends east-west for 30 km. Along the major roads that cross this structure (TO 376 that connects the cities of Pequizeiro and Itaporá, Figure 3 ) no outcrops are found. At the Garrafa creek, south of city of Colméia, there is an excellent exposure of gneiss of the Colméia Complex that is crosscut by veins of granodioritic composition with incipient foliation. Along the same creek, Costa et al. (1988) described migmatitic tonalite and granite cut by small granitic veins.

### *Estrondo Group*

The Estrondo Group crops out in a 15 km-wide belt on both the east and west sides of the Colméia Complex ( Figure 3 ). To the east, rocks of the Estrondo Group are covered by sediments of the Parnaíba basin. The Group consists of fine-grained banded gneisses and muscovite schists. The banded and locally folded gneiss is composed of millimeter-scale layers of biotite, plagioclase and epidote alternating with quartz ( plagioclase) layers ( Figure 4 a). The schist is comprised of chlorite-sericite-epidote rich layers ( Figure 4 b) and quartz carbonate veins/lenses with variable plagioclase contents. A cleavage parallels banding. Locally, a spaced cleavage transposes the banding and the older cleavage ( Figure 4 c).

**Figure 4. Photomicrographs**




Long dimension of the field of view is 1.8 mm.

a. Gneiss of the Estrondo Group unaffected by shearing. B: biotite; P: plagioclase; Q: quartz. Notice zoned epidote (arrow) with allanite core similar to epidote found in schists (compare to b). Plane polarized light.
b. Schist of the Estrondo Group derived by retrograde metamorphism and shearing of gneiss in (a). C: chlorite; S: sericite. Notice zoned epidote (arrows) which survived shearing and retrogression, suggesting derivation of the schist at the expenses of the gneiss Plane polarized light.
c. Chlorite-plagioclase-sericite-quartz schist of the Estrondo Group showing a crenulation cleavage developed during shearing associated with the vertical wrench zones. Crossed polarized light.

Gneisses of the Estrondo Group have higher proportion of feldspar and biotite while schists have higher proportion of white mica and chlorite. The mean mineralogical composition (vol %) of the gneiss is: plagioclase 35, quartz 30, biotite 20, white mica 5, epidote 8, carbonate 2. Schists are made up of white mica 35, quartz 25, chlorite 15, plagioclase 10, biotite 5, epidote 5, and carbonate 5. Microcline is found in only a few gneiss samples. Accessory minerals are tourmaline, opaque minerals, apatite, zircon, and rare titanite and garnet. The mineral paragenesis biotite + quartz + plagioclase + microcline + epidote found in the gneiss belongs to the lower amphibolite facies.

In the shear zones, gneiss was transformed into schist during folding, transposition of the older foliation and generation of a spaced cleavage under lower greenschist facies conditions. Shearing was accompanied by infiltration of H2O - CO2-rich fluid phase, leading to sericitization of feldspars, chloritization of biotite and generation of quartz and carbonate veins and lenses. There are two lines of evidence that schists were generated at the expenses of the gneisses. The first one is that zoned epidote with allanite nucleii are found in both rock types (Figures 4a and 4b). The second is the presence of rocks transitional between gneiss and schist, where biotite and plagioclase are only partially converted into chlorite and white mica, respectively, representing incomplete retrogression. Therefore, one may conclude that the schist was generated by retrograde metamorphism of gneiss in the shear zones, thus not representing the prograde metamorphic equivalent of sedimentary rocks.

### *Tocantins Group*

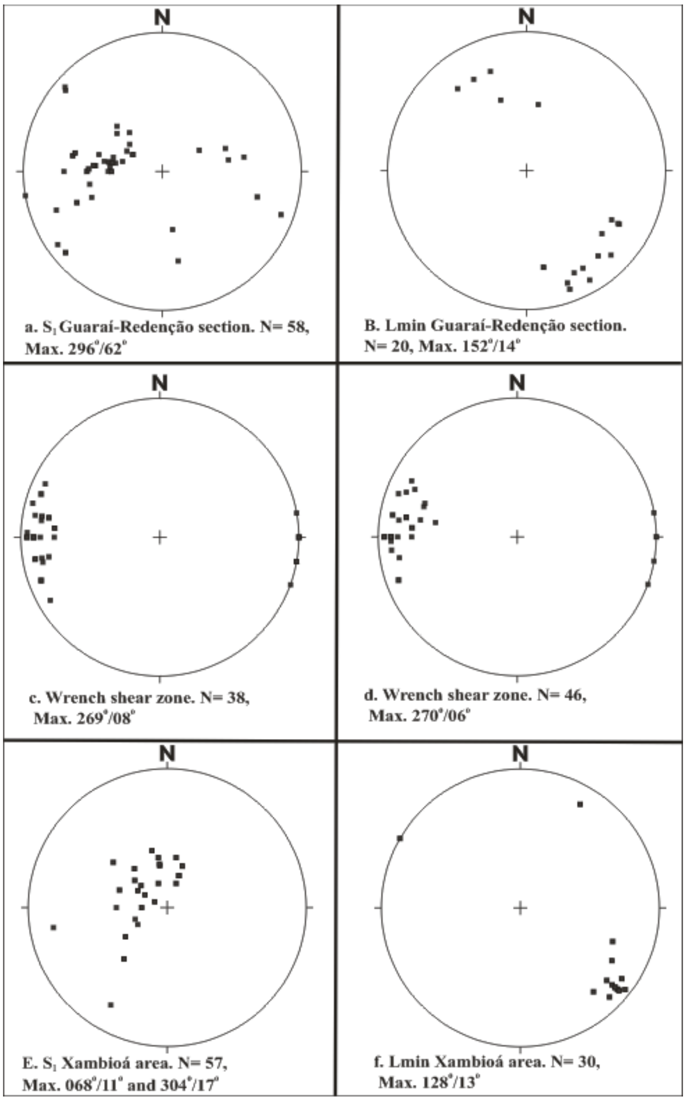
The Tocantins Group (outer zone) crops out for ca 100 km from west of Pequizeiro to nearby Redenção ( Figure 3 ). The rocks are poorly exposed due to deep weathering and flat relief. The best exposures occur in road cuts and in the Serra de São José, 5 km west of Conceição do Araguaia. Slates, phyllites, metasiltites, metasandstones and carbonates form the Tocantins Group. Metamorphism reaches the lower greenschist facies and is absent to the west. The rocks are cut by fine-grained diabases dykes with subophitic textures.

Ultramafic and mafic sequences of unknown age, crops out at the Serra do Quatipuru as well as northwest of Araguacema ( Figure 3 ) in the form of an elongated body. They represent slices of an ophiolite sequence thrusted over the metasedimentary rocks of the Tocantins Group (Teixeira, 1996). The Quatipuru complex is 45 km long and 1-5 km wide and is composed of harzburgites, pods of dunites, massive basalts and pillows basalts at the top. Gorayeb (1989) reports that the body has a regional dip of around 45o to the east and that mylonitic textures occur along the contact with other units.

## Structure

Two sets of structures are reported in the inner zone (Estrondo Group and Colméia Complex): a thrust fabric and a wrench fabric. The thrust fabric comprises a gentle east/southeast dipping gneissic banding or foliation (S1) that strikes N-S. This is the most conspicuous and widespread structure ( Figure 5 a). This N-S striking foliation is axial planar to rare mesoscopic asymmetric F1 folds. Recognition of bedding, however is quite difficult. Bedding was probably transposed during the initial stages of contractional deformation, so identification of F1 folds remains tentative.

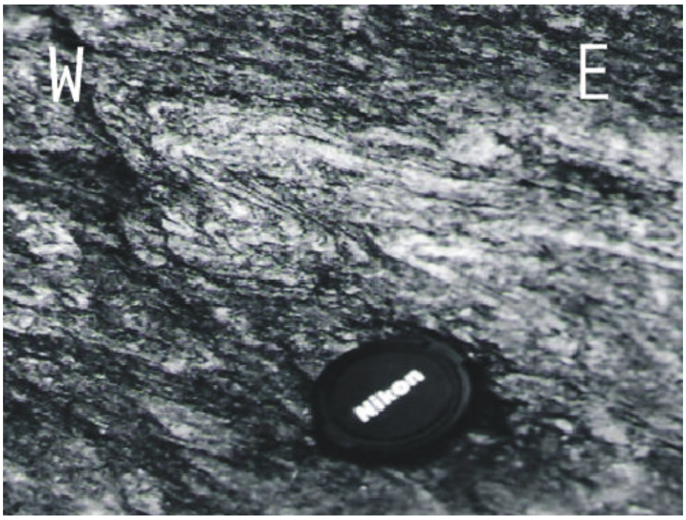
**Figure 5. Stereonet lower hemisphere projection**




Stereonet lower hemisphere projection of structural data of the Guaraí-Redenção section and Xambioá area. a) Poles to foliation of Estrondo Group schists and gneisses; b) mineral stretching lineation, Estrondo Group schists; c) S2 poles to foliation related to wrench shear zone west of Pequizeiro; d) S2 poles to foliation related to a shear zone NW of the previous zone along the road TO 376; e) poles to S1 foliation of Estrondo Group schists and gneisses, Xambioá area; f) mineral stretching lineation, Estrondo Group schists, Xambioá area.

Common F2 asymmetric flexural flow folds (Fig. 6a) fold the gneissic banding / cleavage. They probably represent later stages of regional contractional deformation, for they fold millimeter to meter-scale pre to syn-kinematic quartz veins. A N-S and east dipping spaced cleavage is also present which is axial plane to the F2 folds. Sometimes, the F2 folds have sheath-like forms. Asymmetric centimeter-scale folds are common and represent parasitic folds of larger scale regional asymmetric folds.

**Figure 6. Common F2 asymmetric flexural flow folds**




a. F2 west-verging asymmetrical folds affecting gneissic foliation. Estrondo Group gneiss, outcrop along the road Guaraí-Colméia
b. A second set of vertical cleavage planes locally transposes the first S1 contractional fabric. Outcrop at the Britador quarry (8o 35' 39''S; 48o 51´ 50´´W).
c. S-C fabric at a vertical dextral shear zone. Road Guaraí-Colméia.
d. Z-shaped mesoscopic fold indicating dextral movement in a vertical shear zone. Biotite gneiss exposed at an abandoned quarry flat exposure. Road Pequizeiro-Presidente Kennedy (8o 29' 10''S; 48o 34´ 26´´W).

Quartz stretching lineations are associated with S1. They consistently plunge gently to SSE (150-160o) on east-dipping planes ( Figure 5 b). The recorded rake of the lineation on the foliation plane is about 50-60o towards the south, thus suggesting an oblique movement component. Kinematic indicators such as sigmoidal fabric geometry consistently indicate top to N-NW, as previously described by Hasui and Costa (1990) and Abreu et al. (1994).

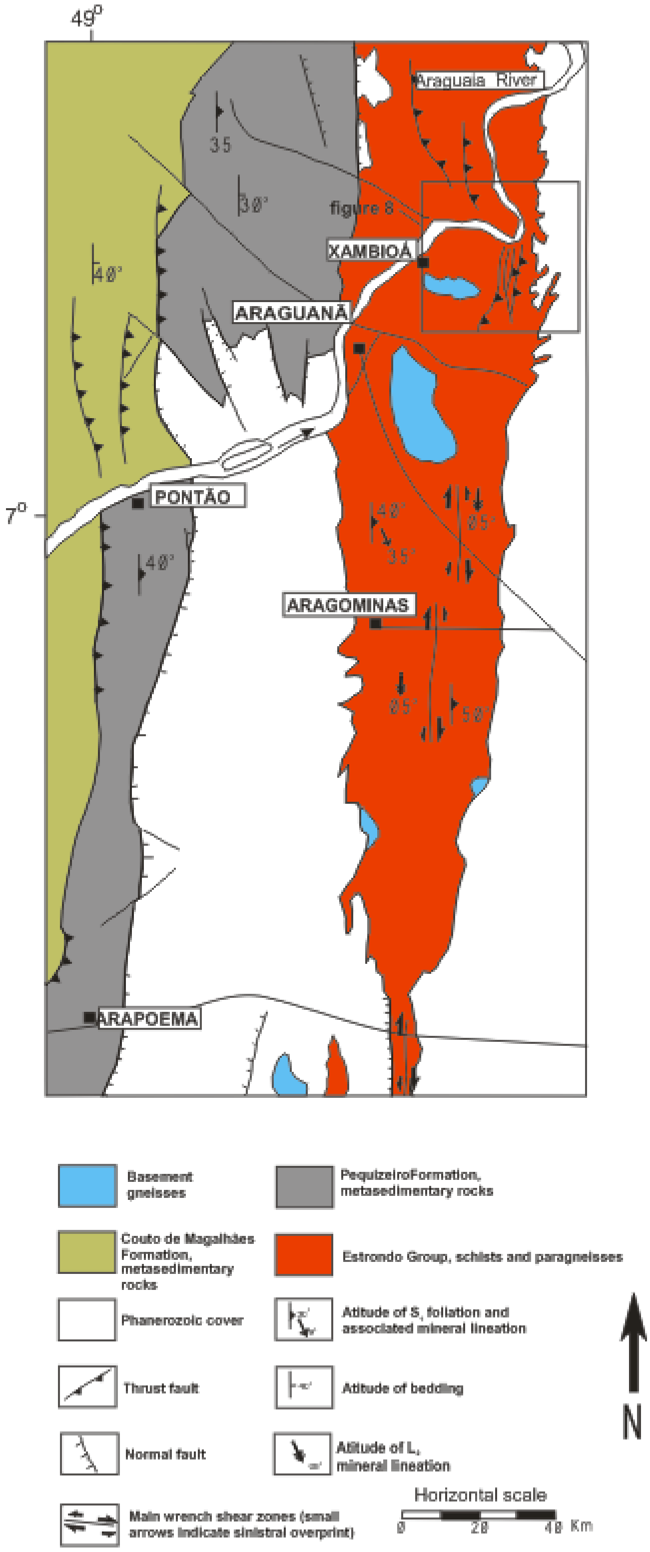
The second set of structures truncates the early thrust fabrics. It consists of a series of north-south ductile-brittle wrench zones. The shear zones, which overprint the gneissic banding, are up to 50m in width and are well developed in both the eastern and western limbs of the Colméia dome. Folds with vertical axis with an associated spaced cleavage locally transpose the gneissic banding ( Figure 6 b). Kinematic indicators, such as asymmetric Z shaped folds and S/C fabric ( Figure 6 c) indicate dextral shear sense.

Three wrench fault zones are best exposed along the west limb of the Colméia dome ( Figure 3 ). The first zone crops out at the Britador quarry, at the margin of the Barreiras river (8o 35' 39"S; 48o 51´ 50´´W). The rock at this quarry consists of felsic migmatitic gneiss with quartz-feldspar leucosomes displaying a complex folding pattern. The wrench zone trends north-south and is vertical with horizontal stretching lineations. Strike-slip movement is also indicated by S/C foliations that cut the gneissic banding. At least two additional shear zones can be recognized along the TO 376 road. Both zones (8o 32' 12"S; 49o 00' 35"W and 8o 32' 37"S; 48o 58' 05"W) affect the Estrondo rocks and display vertical S/C fabrics, with C surfaces trending north and horizontal lineations ( Figure 5 c,d). Another vertical dextral shear zone was identified on the eastern limb of the Colméia Dome. It is located west of the town of Presidente Kennedy (8o 27' 50"S; 48o 35' 44"W) and cuts biotite gneisses. S/C structures are weakly developed but dextral sense of shear is clearly indicated by centimeter-scale Z-shape flexural folds, with vertical hinges ( Figure 6 d).

Extensional brittle structures were also recorded in the inner zone. They affect schists and metasandstones of the Estrondo Group. Centimeter-scale asymmetrically boudinaged veins indicate hangingwall-down to southeast, east of the Colméia dome. Towards the north, these veins are also observed and still indicate normal movements. At the southern boundary of the Lontra dome, the veins cross-cut metasandstones of the Morro do Campo Formation (Estrondo Group) also indicating normal movement to the south. The significance of this normal set of brittle structures is still unclear.

Normal faults bordering the Xambioá dome are also common. Excellent exposures of normal faults that indicate top-down to the NNW can be observed along the road cuts, 3 km south of Xambioá, along the road TO 388 ( Figure 7 ).

**Figure 7. Central portion of the Araguaia Belt**




Central portion of the Araguaia Belt (Xambioá area) with location of the main F2 shear zones. See Fig. 2 for location. Geology after Silva et al. (1974).

In the low-grade outer zone, a single set of thrust-sense structures, recording east-west shortening, is observed. Metapelites in this zone exhibit a slaty or spaced cleavage. Its relation to bedding indicates the presence of regional-scale asymmetric folds, but fold hinges have not been identified. A positive Bouguer gravity anomaly (Carvalho, 1988) from Conceição do Araguaia (approximately in the transition between the inner and outer zones) to the west suggests that basement is shallower in the outer zone compared with the inner zone. The relation between the ultramafic bodies and supracrustal rocks of the Tocantins group is unclear, however the presence of mylonitic foliation along the border of the Quatipuru complex favors a tectonic relationship (Gorayeb, 1989).

### *Extension of the wrench faults to the north*

N-S trending shear zones mapped along the Guaraí-Redenção profile can also be recognized in the northern part of the Araguaia Belt ( Figure 7 ) where they are well developed east of Arapoema (7o 39' 61"S; 49o 00' 65"W). There, gneisses of the Estrondo Group exhibit meter-scale dextral shear zones. Figure 2 shows that this zone is located immediately north of the previously described zones, along the same meridian as the wrench zones mapped near Pequizeiro.

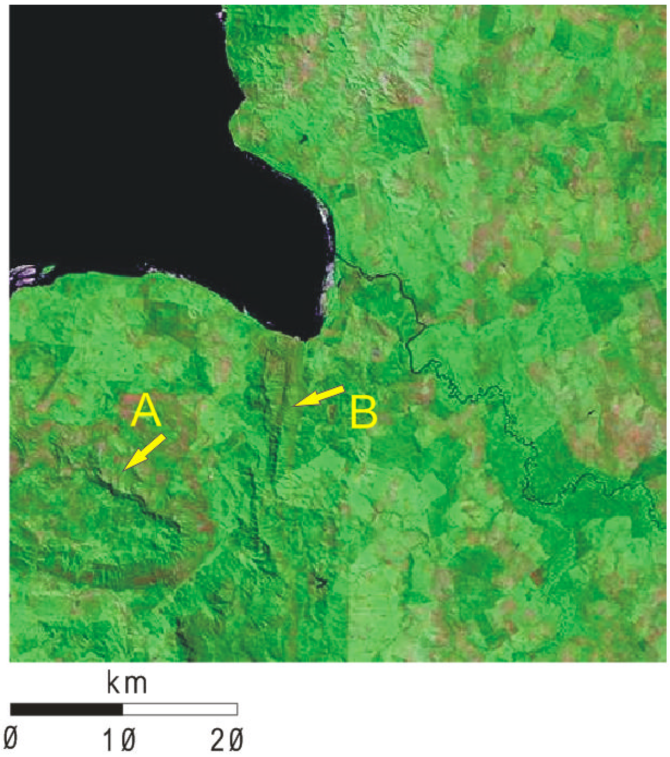
Farther north, wrench shear zones are conspicuous east and northeast of Aragominas ( Figure 7 , herein named Xambioá area). The regional structure of the Xambioá area is strongly controlled by the presence of two domes, the Xambioá to the north and the Lontra dome to the south. Previous structural studies indicate thrust contacts between domes and supracrustal rocks of the Estrondo Group (e.g. Santos and Costa, 1995). However, we re-examined the contacts and found that they actually represent high-angle normal faults. Effectively, the Estrondo Group forms a keel between both domes. The Estrondo rocks record also thrust faults and F1 and F2 mesoscopic folds that verge to the west. S1 foliation trends NNE and NS, with mineral lineation plunging to the southeast, thus confirming the oblique character of the thrust fabric ( Figure 5 e, f).

Strongly sheared shallowly dipping gneissic banding is truncated by a vertical set of high-angle dextral shear zones at the Umuarama quarry (east of Aragominas, 7o 11' 71"S; 48o 26' 68"W, Figure 7 ). Schists and gneisses of the Estrondo Group are cross cut by vertical shear zones with evidence of sinistral reactivation of dextral fabrics northeast of Aragominas (6o 55' 68"S; 48o 28' 48"W). The meaning of this sinistral fabric is still unclear.

These high angle shear zones represent the northward extension of those mapped between Itaporá and President Kennedy, ca 200 km to the south ( Figure 2 ). This confirms the regional extent of the wrench tectonics.

The wrench shear zones of the Araguaia belt are not visible in satellite images as the shear zones in the Borborema. North-south lineaments on Landasat TM images (Miranda and Coutinho, 2004) of the Xambioá dome area ( Figure 8 ) were mapped as west-verging thrusts of the first deformation phase.

**Figure 8. Landsat TM image of the Xambioá dome area**

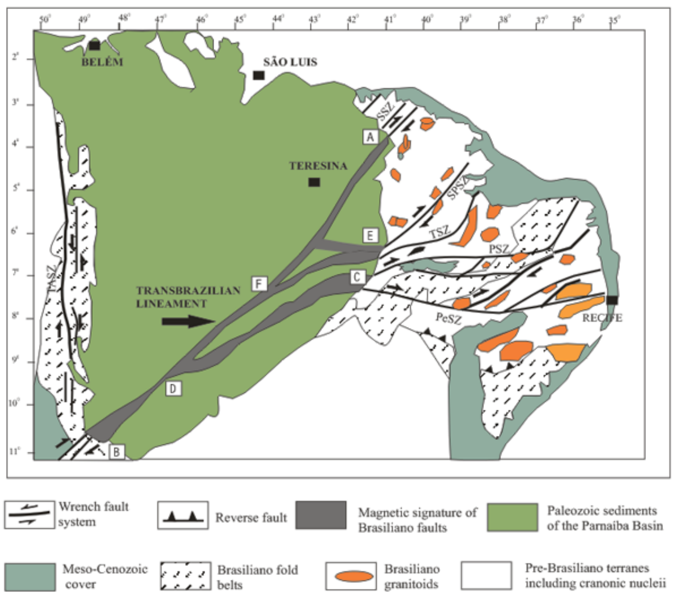



Landsat TM image of the Xambioá dome area (Miranda & Coutinho, 2004). Arrow A indicates the Xambioá Dome and B indicates north-south lineaments mapped as west-verging D1 thrusts that cut across metasedimentary rocks of the Estrondo Group. Wrench shear zones of the Araguaia belt are not visible in satellite images, unlike those of the wrench shear zones in the Borborema. See Fig. 7 for location.

## *The Araguaia Belt in the Gondwana Amalgamation Scenario: a Tentative Kinematic Fit*

Recent models involving the triple collision among West African, São Francisco Congo and Amazonian cratons have been proposed by Castaing et al. (1993, 1994), Alkmim and Fonseca (1998) and Alkmim et al. (2001). All these models propose that the collision caused oblique tectonics, mainly recorded by the network of dextral shear zones exposed in the Borborema Province. This network of dextral shear zones in the Borborema Province is just a small part of a much greater orogen, the Brasiliano-Pan African chain ( Figure 9 ). This orogen includes major strike-slip component ductile shear zones that rework basement fragments and affect supracrustal rocks (Borborema, Nigerian and Central African Provinces) and metasedimentary frontal thrust fold belts facing the São Francisco Craton (Sergipano and Oubanguides Fold Belts) to the south and the West African Craton (Dahomehides and Gourma Fold Belts).

**Figure 9. Tentative correlation between the Araguaia fold belt**

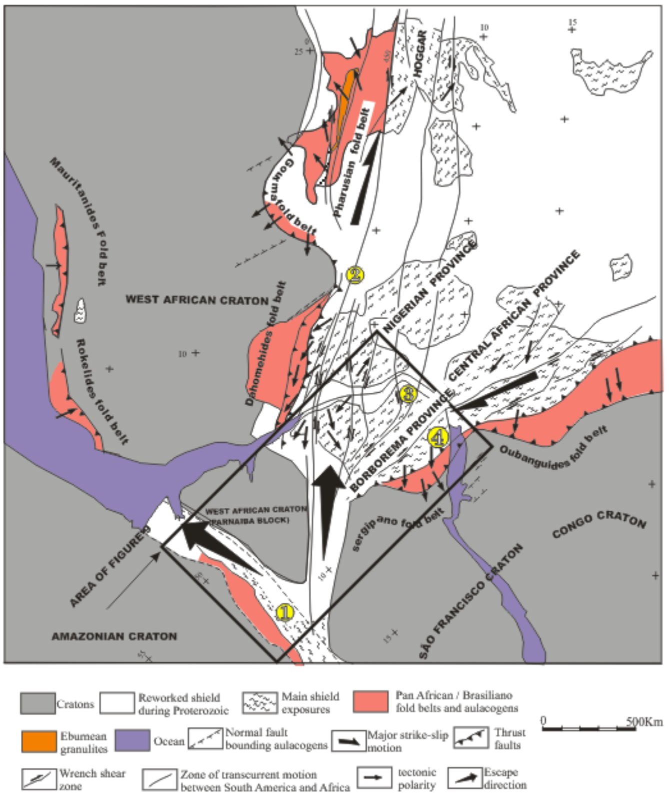



Tentative correlation between the Araguaia fold belt wrench structures and the Borborema Province. Structures of the Borborema Province after Vauchez et al. (1995). Magnetic signature of the wrench structures after Goes et al. (1993). All transcurrent structures root at the Transbrasilian Lineament beneath the Parnaíba Basin and merge in the SW corner of the Araguaia Belt. The Araguaia Belt represents a physically independent fault array. Note that most of the Parnaíba Basin lies upon an area not apparently affected by the Brasiliano-Panafrican tectonism, thus extending to SE the limits of the West African Craton. Main Shear Zones: SSZ: Sobral; SPSZ: Senador Pompeu; TSZ: Tatajuba; PSZ: Patos; PeSZ: Pernambuco; TASZ: Tocantins-Araguaia Shear Zone.

The correlation between the Borborema fault array and the north-south wrench structures of the Araguaia Belt, however, is concealed beneath the Parnaíba Paleozoic Basin ( Figure 1 ). To search for a possible correlation, we used magnetic data on the structure of the Parnaíba Basin presented by Goes et al. (1993). Magnetic data suggest that the 4o 50´ Hoggar ductile lineament in Africa traces to the southwest into Brazil (herein named Sobral lineament), and reaches the Parnaíba basin at its NE corner (parallel 4o, point A in Figure 9 , Vauchez et al., 1995). Its magnetic signature runs S 50o W and emerges at the southern boundary of the Araguaia Belt (parallel 11o, point B in Figure 9 , and Figure 2 ). The array of wrench fault zones in the Central Chain (Borborema Province) as proposed by Vauchez et al. (1992) may be traced westwards as follows: the Potengi Shear Zone (western extension of the Patos Shear Zone) merges the Pernambuco Shear Zone (C in Figure 9 ) and then trends to S 60o W, rooting into the Transbrazilian lineament at 46o 30' W/9o 30´S, (D in Figure 9 ). The Senador Pompeu Shear Zone joins the Tatajuba Shear Zone (E in Figure 9 ) and runs parallel to the Pernambuco Shear Zone, also rooting into the Transbrazilian Lineament at 44o W/8o S (F in Figure 9 ), with a small branch running EW at parallel 6 o.

Analysis of Figure 9 also shows that a great extension of the Parnaíba Basin (the area north of point B in Figure 9 ) is not affected by Brasiliano structures, suggesting that it represents a small Brasiliano cratonic block (the Parnaíba Block, see Figure 10 and compare with Figure 1 ).

**Figure 10. The Araguaia Fold Belt**




1. (numbers in filled yellow circles) as part of a continental-scale strike-slip system in the Neoproterozoic (simplified after Castaing et al., 1994).
2. Frontal Fold Belts facing the West African Craton.
3. Borborema, Nigerian and Central African Provinces: major strike-slip component ductile shear zones that rework basement fragments and affect supracrustal rocks.
4. Frontal Fold Belts facing the São Francisco Craton. In such reconstruction, the combined movement on the Araguaia-Borborema strike slip systems accommodated respectively northward and northeastward escape of wedged terranes between Amazonian and West African Cratons and São Francisco / Congo and West African Cratons.

In such a reconstruction, the set of north-south wrench faults of the inner zone of the Araguaia Belt would represent a shear corridor, located between the south-southwestern border of the West-African Craton and east Amazonia ( Figure 10 ). This shear corridor, operating as another escape fault array, allowed the intervening material (the supracrustal units of the Araguaia between the two cratonic blocks) to squeeze northwards as the result of the transcurrent relative motion between Amazonian and The West African Craton. This shear movement between the Amazonian and São Francisco Craton was previously postulated by Castaing et al. (1994).

The age of this Brasiliano escape tectonics in the Borborema province is constrained by 40Ar/39Ar and U/Pb. 40Ar/39Ar plateau ages allow definition of homogeneous slow cooling between 580 and 500 Ma. Fast cooling around 500 Ma (related to significant uplift during lateral escape) is suggested by concordant plateau ages on muscovite and biotite ages (Corsini et al., 1988; Neves et.al., 2000). Alkmim et al. (2001) suggested the escape was late Brasiliano in age because the east-west related structures of the Borborema fault array truncate older structures related to São Francisco/de La Plata collision with Amazonia. The difference in metamorphism between the greenschist - amphibolite facies exposed rocks of the Araguaia belt and the amphibolite to granulite facies rocks exposed in the Borborema Province, may be related to a combination of exposure level and to regional variations in heat flux over this vast area.

## Conclusion

New structural data collected along the type-section of the Araguaia Belt provides the basis for a new tectonic model of the region. We propose that two deformational phases affected the region: the first involves north-trending foliation dipping E and recording oblique sinistral thrusting, with structural vergence towards the Amazonian Craton. This phase is well displayed in the metasedimentary rocks of the Estrondo Group in the inner zone of the Araguaia Belt and was accompanied by amphibolite facies metamorphism. The second deformational phase is represented by orogen-parallel wrench tectonics leading to the development of vertical north-south trending shear zones. This second set of structures overprints the thrust fabric of the Estrondo Group and is responsible for the development of a retrograde metamorphism in the inner zone. An intervening phase of doming is inferred due to the existence of extensional fabric around the domes.

This tectonic model does not answer some questions regarding the tectonic evolution of the Araguaia Belt. For example, the reasons for the abrupt metamorphic contrast and difference in structural style between the inner and outer zones. Likewise, the significance of the Tocantins-Araguaia shear zone, the significance of the mafic-ultramafic bodies situated towards the foreland and finally the mechanism of dome generation are unclear.

The age of the strike-slip overprint has not been determined. But considering the tectonic framework of Congo-São Francisco, Amazonian and West African block interaction and the extension of the West African Craton limits to the south, we propose that strike-slip faults connect with the east-west trending dextral strike-slip faults in the Borborema Orogen on the northern margin of the São Francisco Craton through the Transbrasilian lineament buried under the Parnaíba cover sequence.

In summary, the Araguaia Belt, described as part of the Tocantins orogen, records two events. The older event, possibly Paleoproterozoic resulted in a fold and thrust belt verging towards the Amazonian craton. We postulate that by the end of the Brasiliano/Pan-African orogeny, the Araguaia Belt accommodated northward lateral escape of terranes wedged between the Amazonian and West African Cratons, overprinting its inner zone and deforming the younger Neoproterozoic strata of the Couto de Magalhães and Pequizeiro Formations in its outer zone.

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